The Rubble-House Project at SPSU: Full-Scale Construction, Testing, and Measurement Experience

Fatih Oncul, Ph.D., Civil Engineering Technology

Wasim Barham, Ph.D., Civil Engineering

Pavan Meadati, Ph.D., Construction Management

Jeremy Holloman, Conscience International

Jacob David, Senior CET Student

ASCE-GA Section Meeting – February 3, 2012

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Presenters

- **Jeremy Holloman, Conscience International, Inc.**
- **Wasim Barham, Ph.D., Civil Engineering**
- **Pavan Meadati, Ph.D., Construction Management**
- **Jacob David, Senior CET Student**

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Introduction

- Started at one of ASCE-GA meetings
- SPSU and Conscience International, Inc. Partnership
- Construction work at the center of the campus..
- A project with no budget!
- Locally sponsored.
- Campus-wide involvement..

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Rubble in Haiti

- Jan 2010 Earthquake generated 20 million cubic yard of rubble
- As of now only 50% were removed
- New construction activities will generate more rubble
- Rubble recycle efforts by cash-for-rubble program

In Haiti

(a) Foundation installation

(b) Wire basket preparation

(c) Baskets filled with loose rubble

(d) Adjusting window and door openings

(e) Applying cement finish

(f) Roof installation

(g) Final look of a typical Rubble-House in Haiti

SOUTHERN POLYTECHNIC STATE UNIVERSITY

At SPSU

(a) Foundation installation

(b) Wire basket installation

(c) Wire baskets being filled with loose rubble.

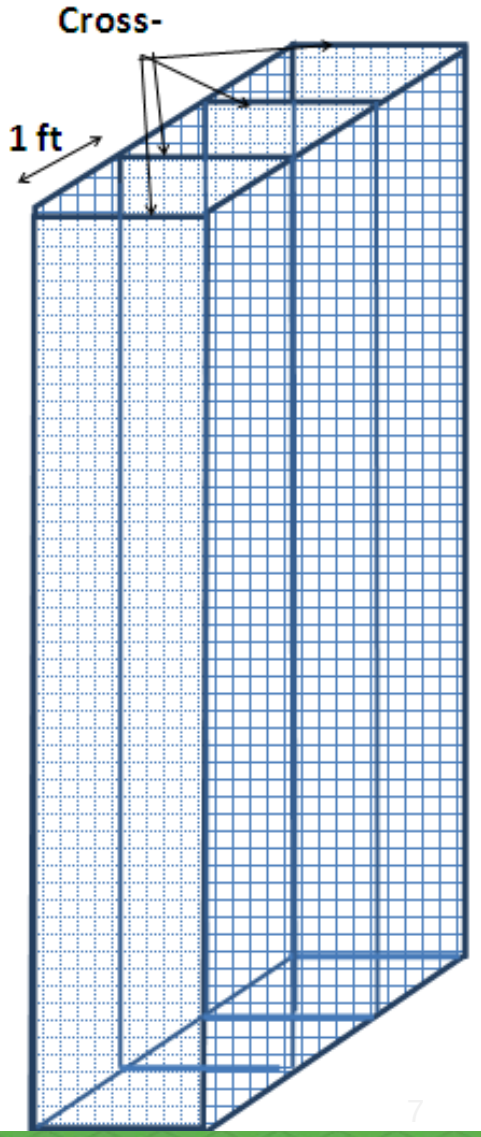
(d) Applying cement finish

(e) Final look of the rubble-house on SPSU campus.

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Wire Basket


23-Gauge flexible wire fabric
10-Gauge welded wire mesh
6 in
6 in
10-Gauge cross tie


Cross-
1 ft

Demonstrations with Concrete Battering Ram.

Brick Wall

Rubble Wall

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Research Phases

- Phase 1: Preliminary, static loading, sponsored locally, @ SPSU **(~$75,000)**

- Phase 2: Comprehensive, full-scale shake table test(s), sponsored by NSF? @ University of Buffalo? **(~170,000)**

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Objectives of Phase 1

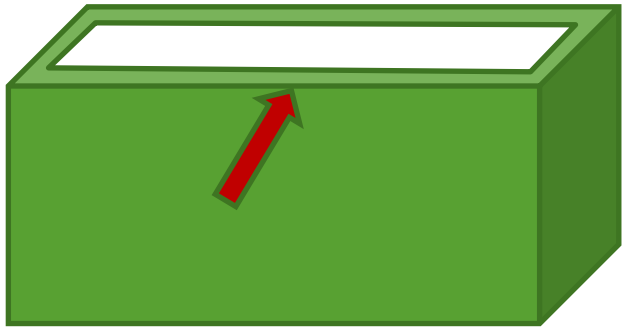
- Evaluate current construction techniques and propose cost-effective improvements
- Perform static load testing on a full-scale RUBBLE-HOUSE
- Create computer models for static and dynamic analyses
- Make recommendations for future seismic shake table experiments
- Draft construction and design guidelines based on experimental and numerical findings

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Static Field Load Testing Schedule - Phase 1

Test 1

Test 2

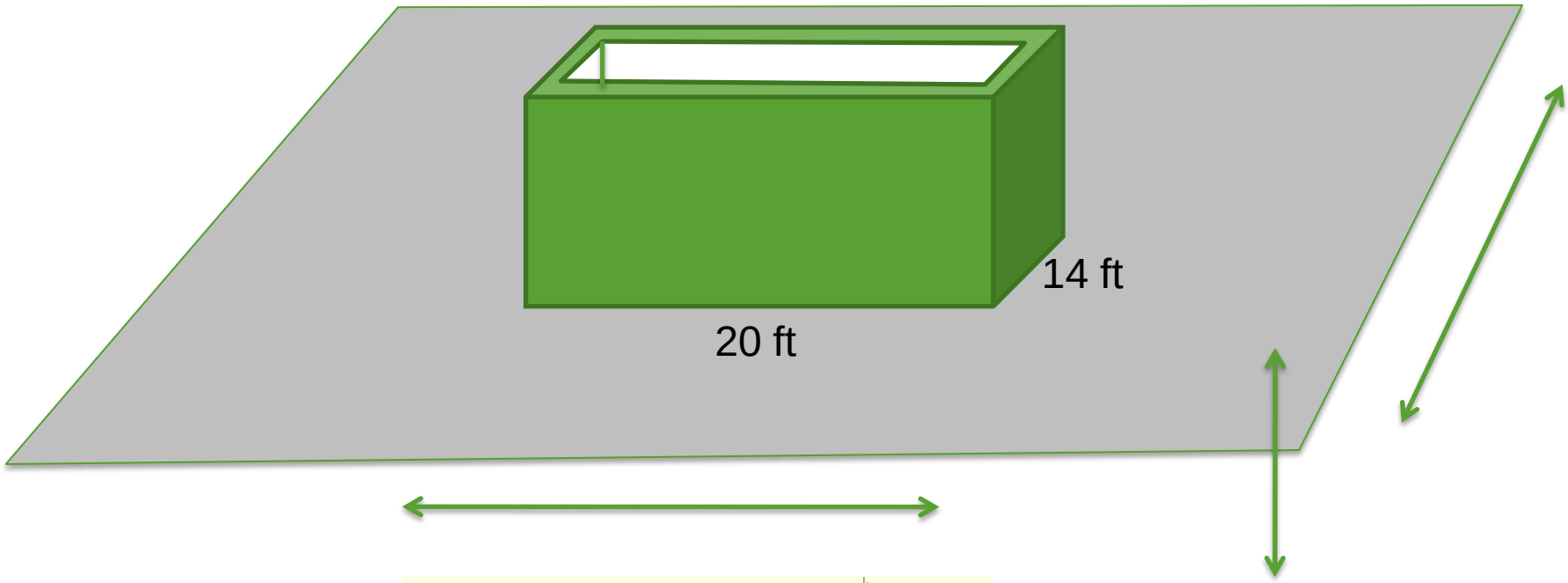


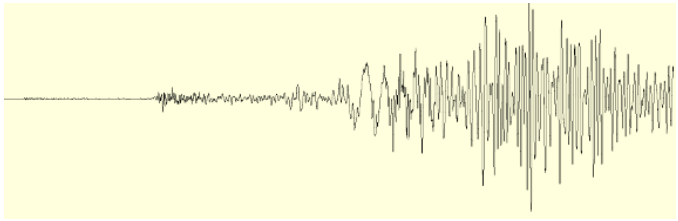
Test 3

Objectives of Phase 2

- Perform full-scale shake table tests
- Study compaction behavior of the rubble under a main seismic event and series of aftershocks
- Determine failure modes
- Study the performance of proposed improvements from Phase 1
- Develop rubble house construction guidelines

Seismic Shake Table Test - Phase 2





SOUTHERN POLYTECHNIC STATE UNIVERSITY

Measurements

- Three Methods
  - Displacement gauges
  - Total Stations
  - 3D Laser

(a) Displacement gauges.

(b) 3D Laser scanner.

(c) Total stations.

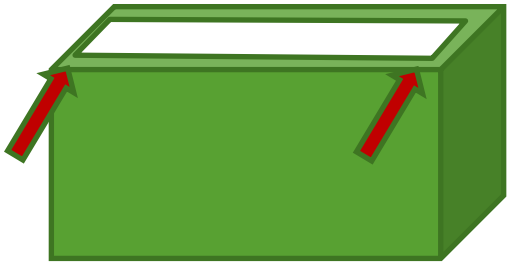
Field Tests

Dr. Wasim Barham
Civil Engineering

SOUTHERN POLYTECHNIC STATE UNIVERSITY

TEST 1

- In-plane push



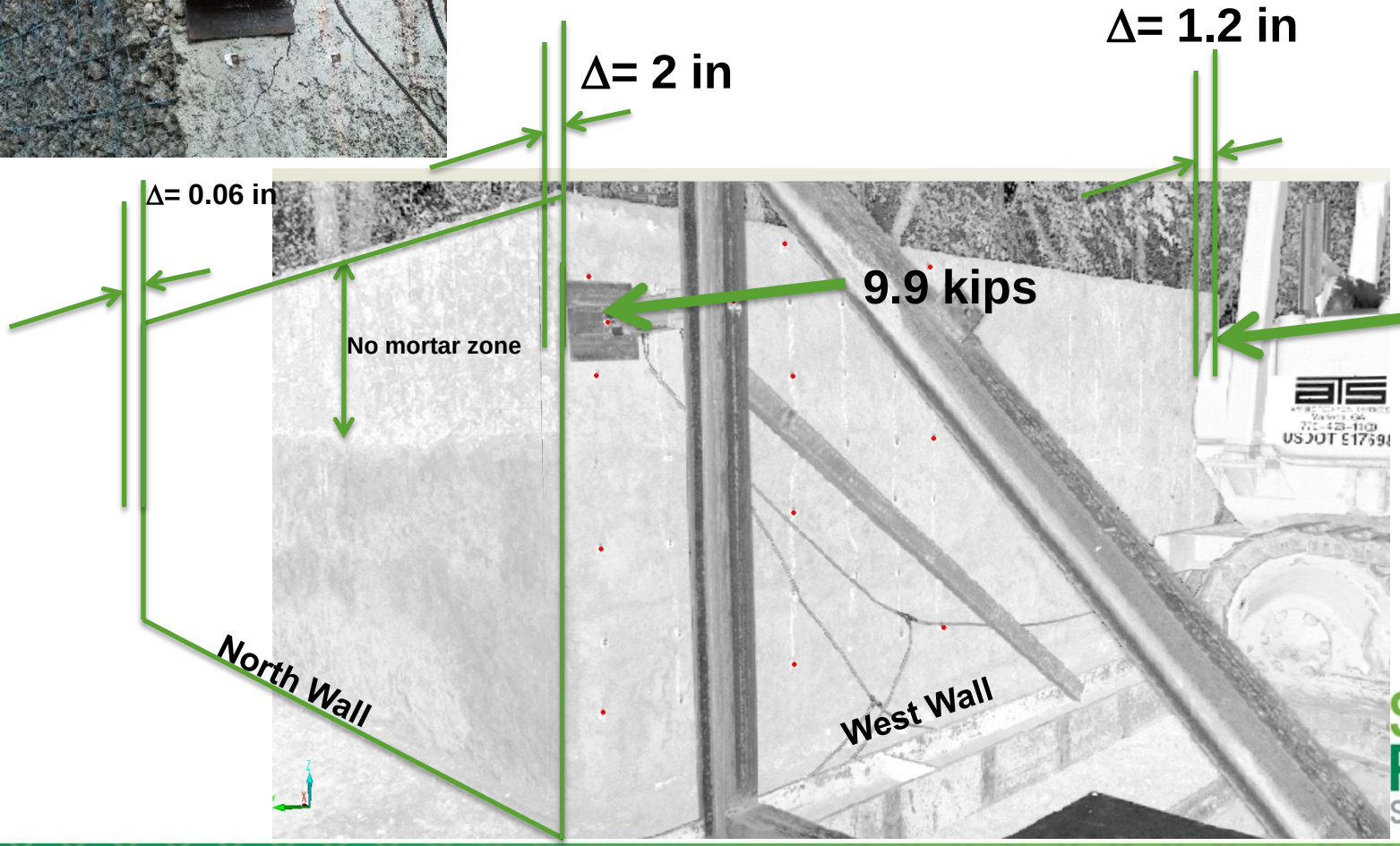
(a)

(b)

(c)

(d)

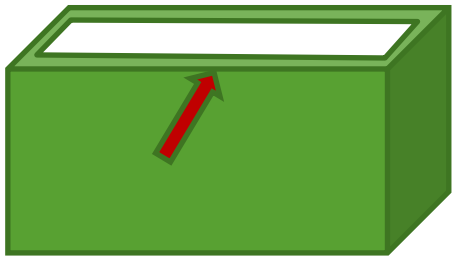
TEST 1



SOUTHERN POLYTECHNIC STATE UNIVERSITY

TEST 2

- Center push



(a)

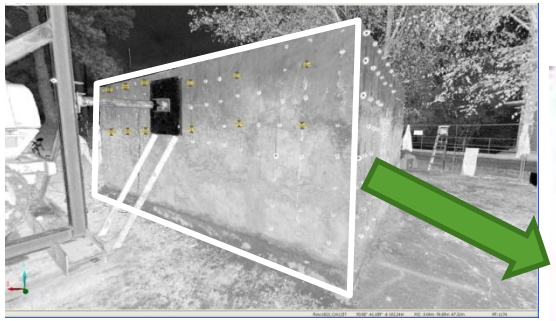
(b)

(c)

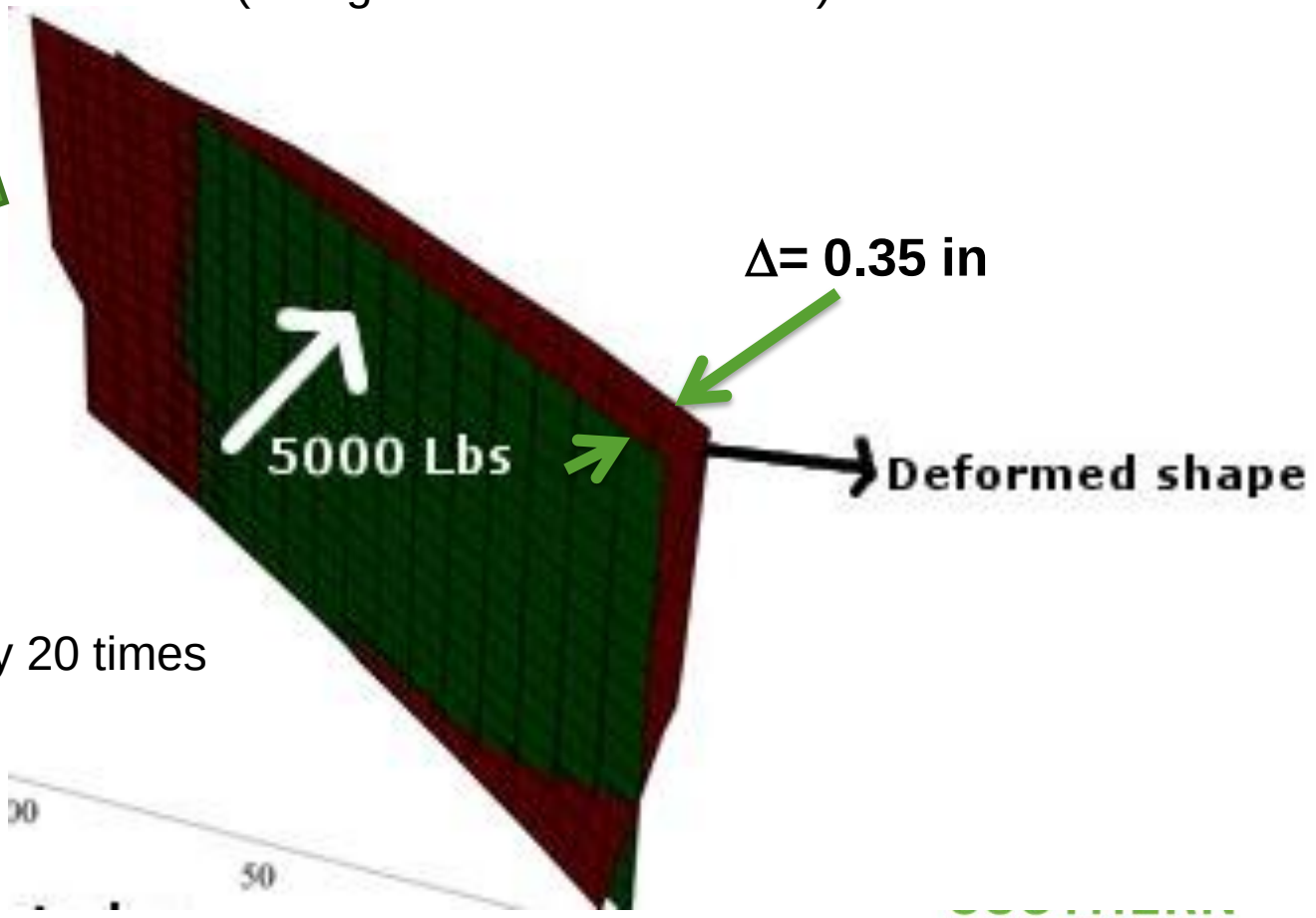
(d)

3D Laser Scan Picture – Test 2: Center Push

Deformed Shape – West Wall

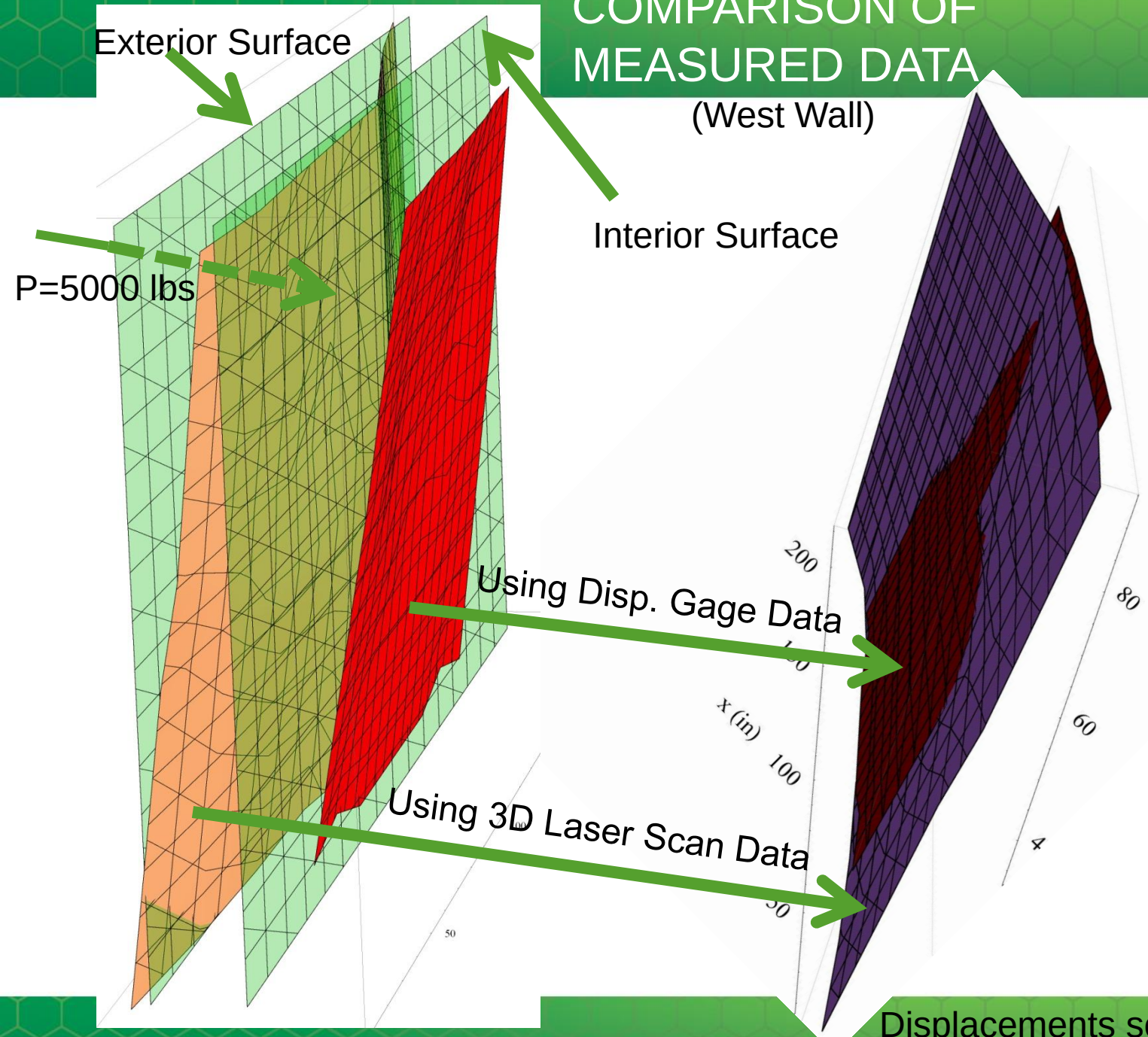


(Using 3D Laser Scan Data)



Displacements scaled by 20 times

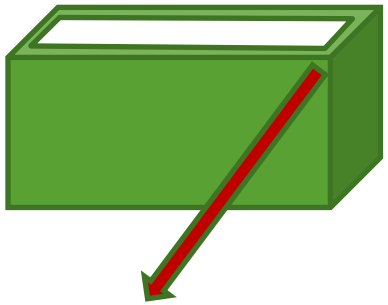
COMPARISON OF MEASURED DATA



Displacements scaled by 20 times

TEST 3

- Destructive



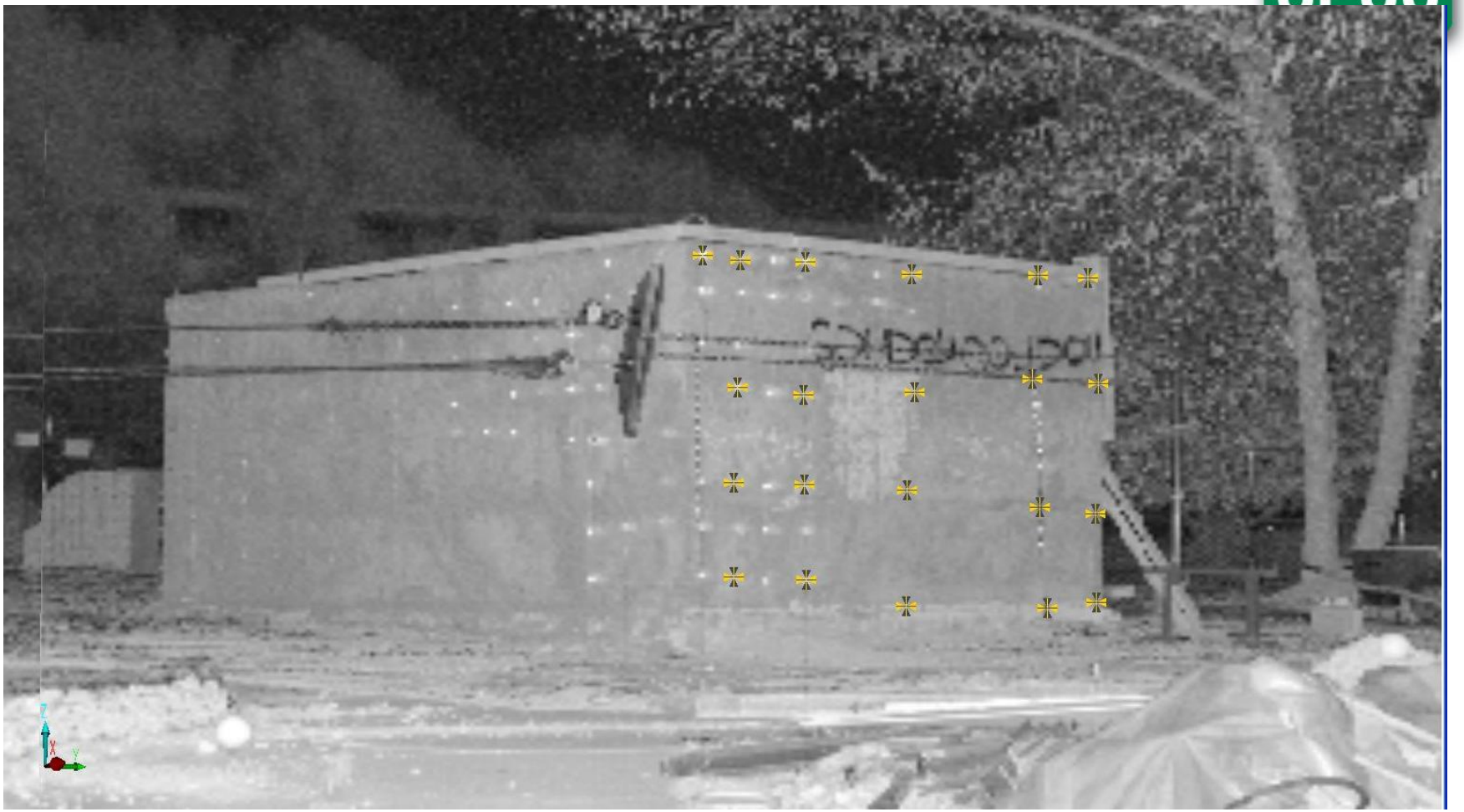
(a) Truck with a front winch.

(b) Wrap around chain link.

(c) Load gauge.

(d) Wooden block at SE corner.

3D Laser Scan Picture – Test 3: Destructive



Video: Part I

Video: Part 2

Video: North Wall

Post-failure

Maximum Horizontal Displacement = 3.5 ft

Maximum Horizontal Load = 15 kips

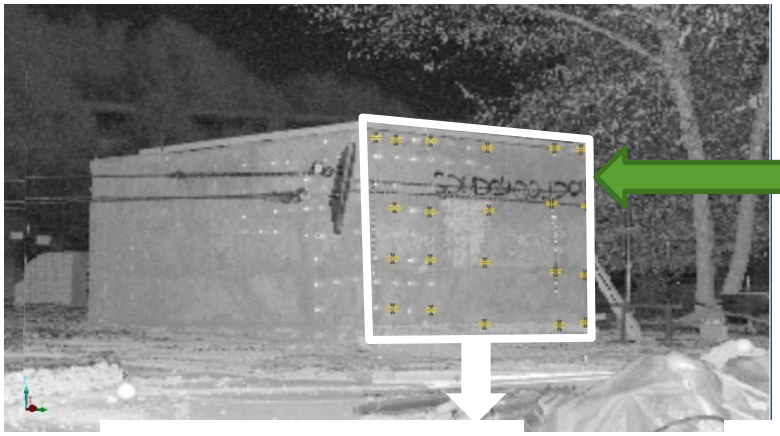
(a) Rubble-House after failure

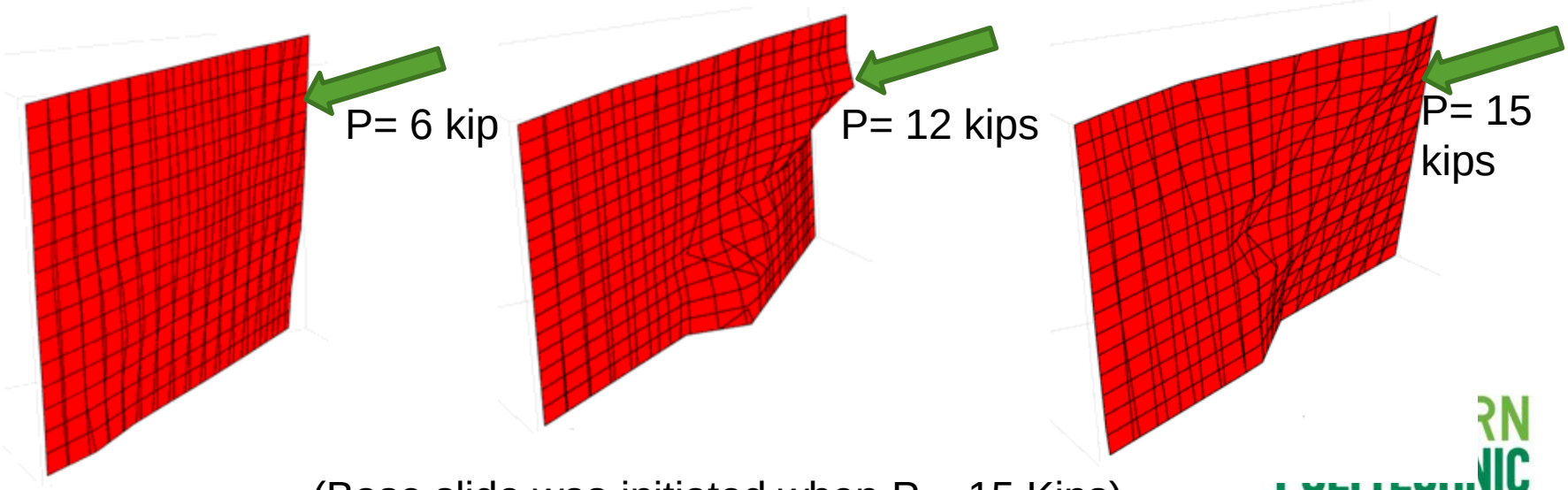
(b) South-east corner.

(c) South-east corner bottom.

Deformed Shape – South Wall

(Using 3D Laser Scan Data)





(Base slide was initiated when P ~ 15 Kips)

Displacements scaled by 20 times

3D Laser Scanner

Dr. Pavan Meadati

Construction Management

SOUTHERN POLYTECHNIC STATE UNIVERSITY

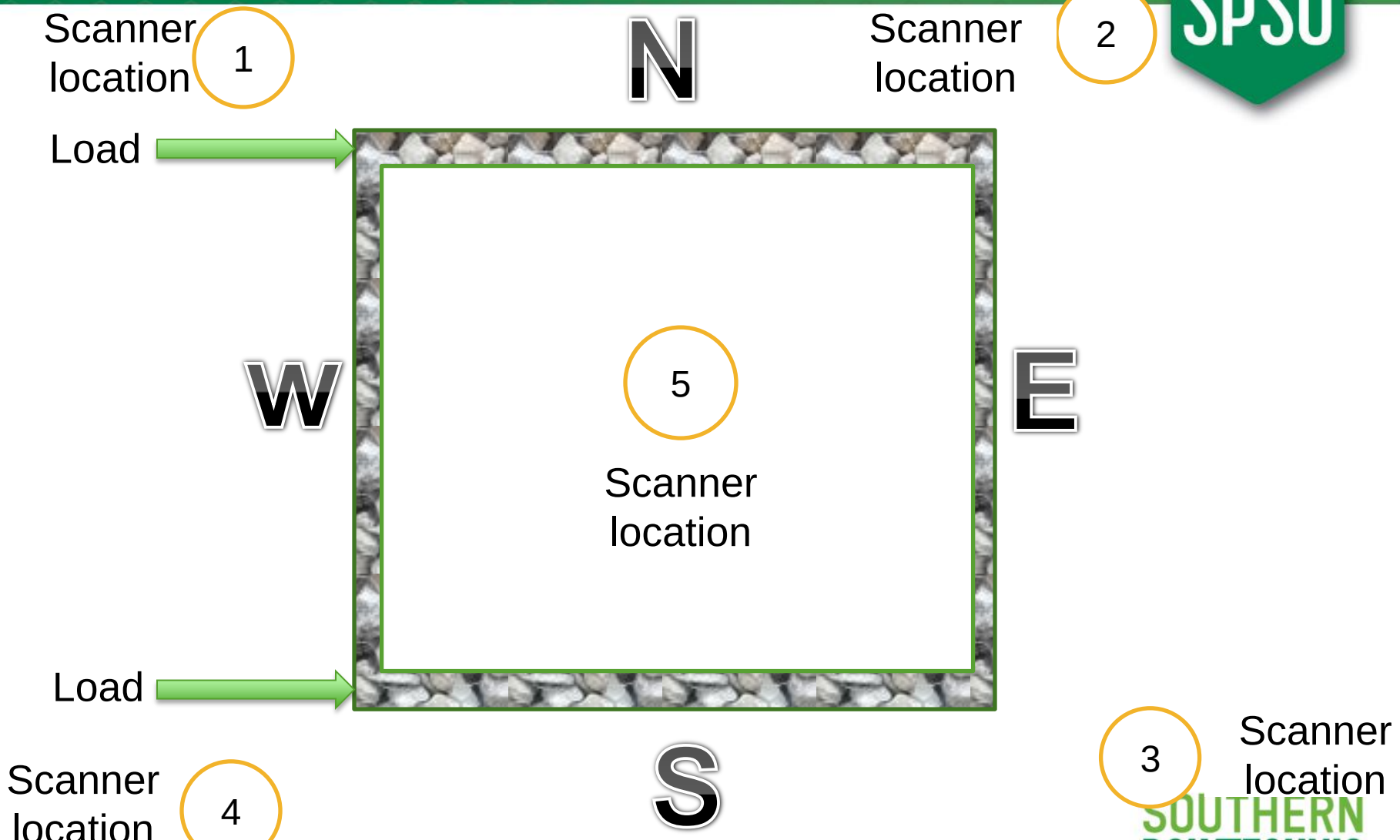
3D Laser Scanner

- 2 FARO brand scanners were used
  - Focus 3D
  - Color
  - Single scan time ~ 15 min
  - Multiple scans at selected load increments.
  - Failed !!

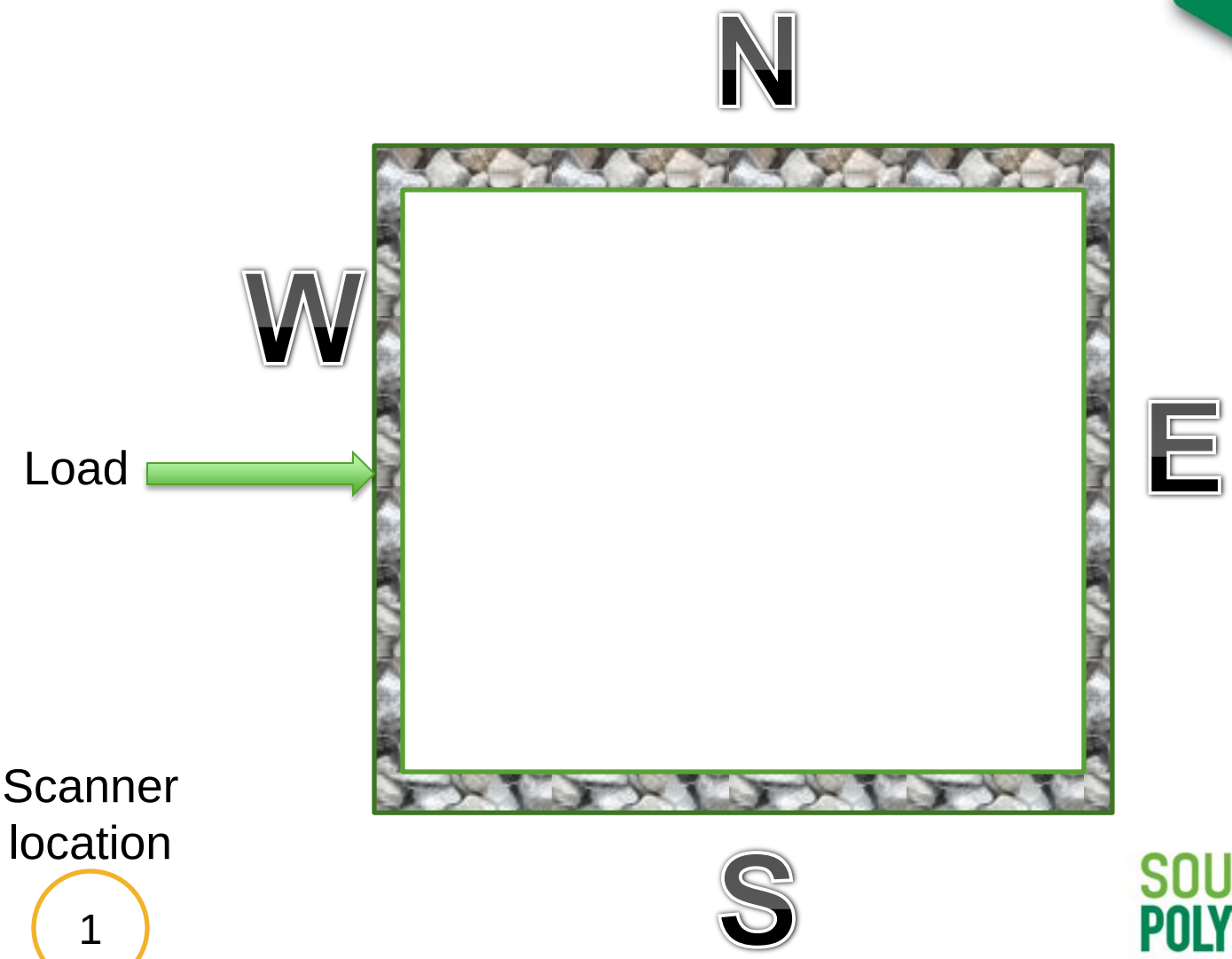
  - Photon 20
  - B&W
  - Single Scan time < 5 min
  - One scan at selected load increments

SOUTHERN POLYTECHNIC STATE UNIVERSITY

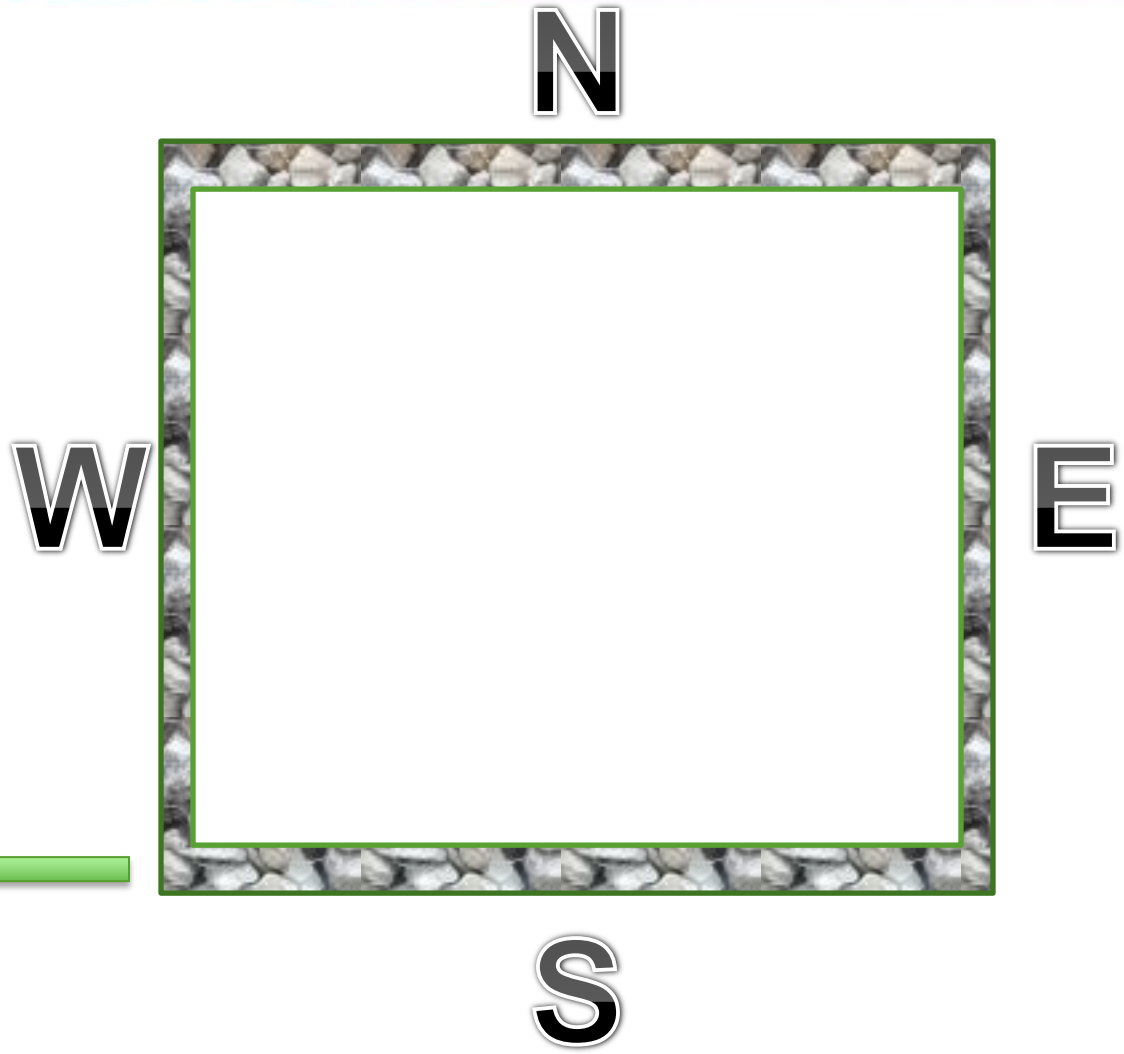
TEST 1 –Scanner Locations



TEST 2 –Scanner Location



TEST 3 –Scanner Location



Faro Laser Scanner Focus 3D

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Faro Laser Scanner Photon 20

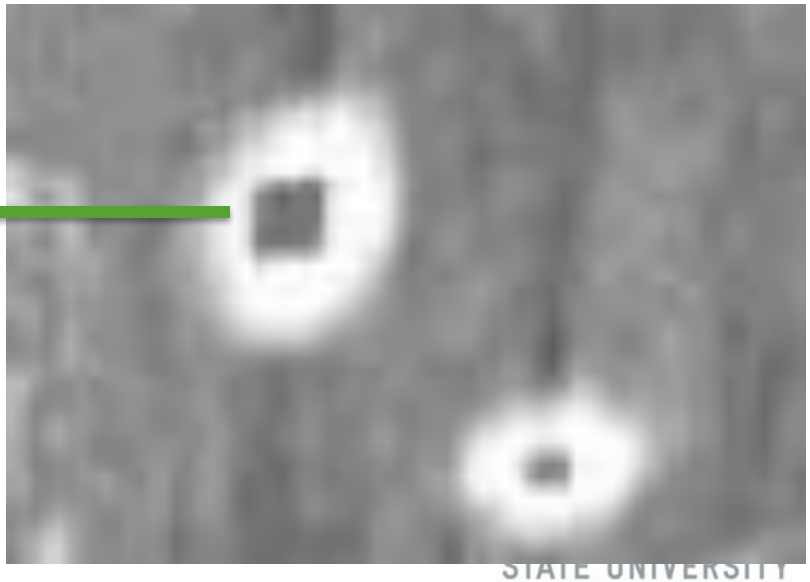
SPSU

SOUTHERN POLYTECHNIC STATE UNIVERSITY

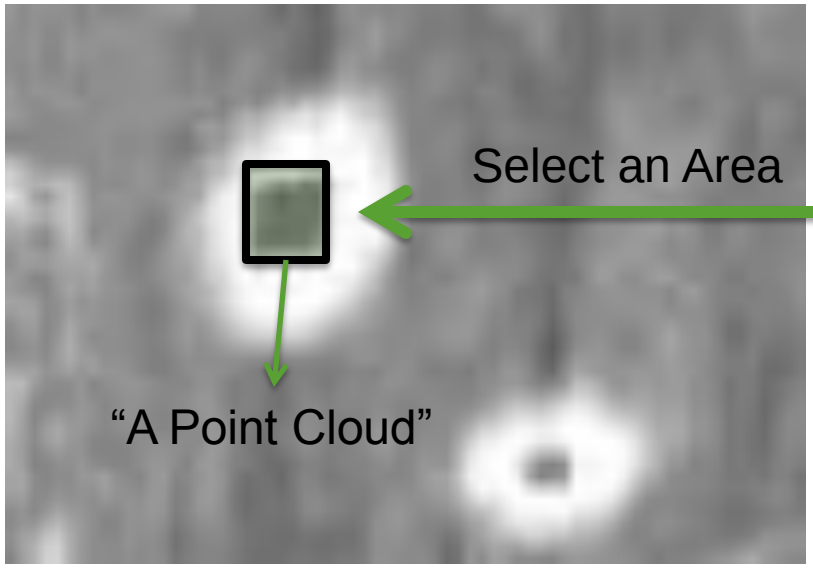
Post Processing

Select a Spot

Zoom in



Select an Area



“A Point Cloud”

Campus & Community Involvement

Jacob David

Senior CET Student

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Vehicle of Opportunity

- Provide a way for faculty & students to engage learning material in field
- Develop collaboration between SPSU and the surrounding community

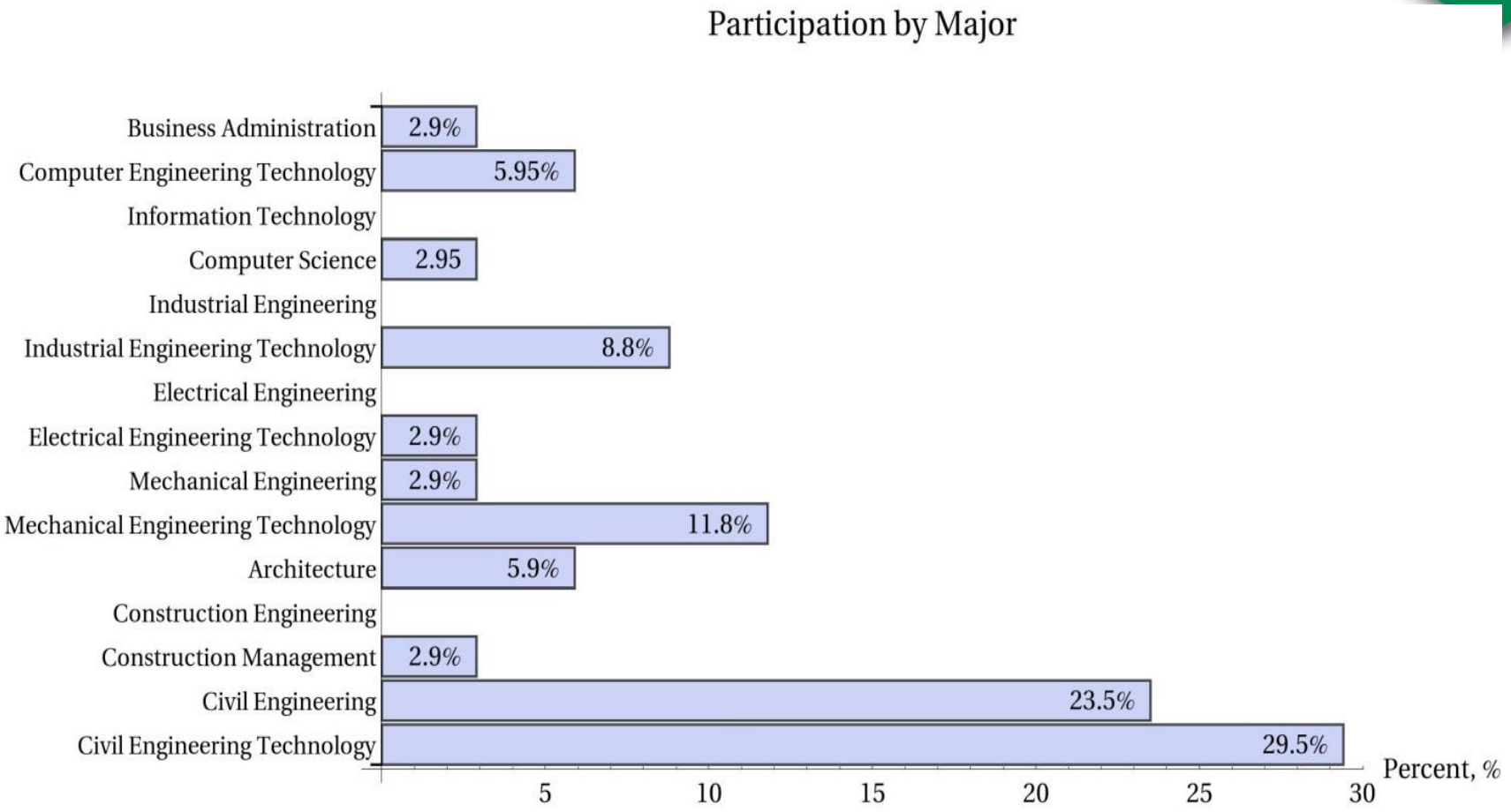
SOUTHERN POLYTECHNIC STATE UNIVERSITY

Student Involvement

- Objectives:
  - Focus and apply engineering skills learned in the classroom to the field environment
  - Enhance professional communication and networking skills through teamwork
  - Develop a sense of community amongst faculty and students, while supporting a good cause
- ~ 100 volunteers participated
- 600 labor hours over construction period

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Student Involvement



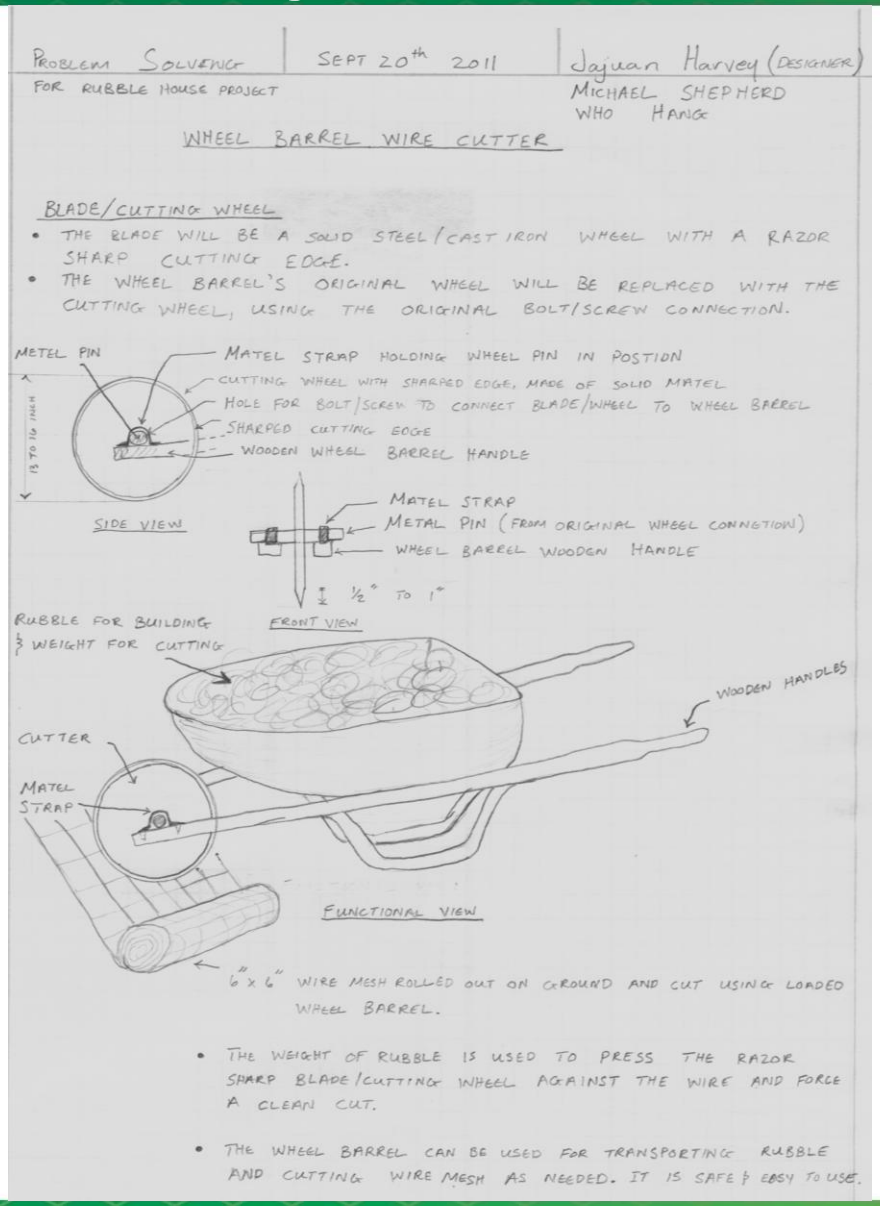
SOUTHERN POLYTECHNIC STATE UNIVERSITY

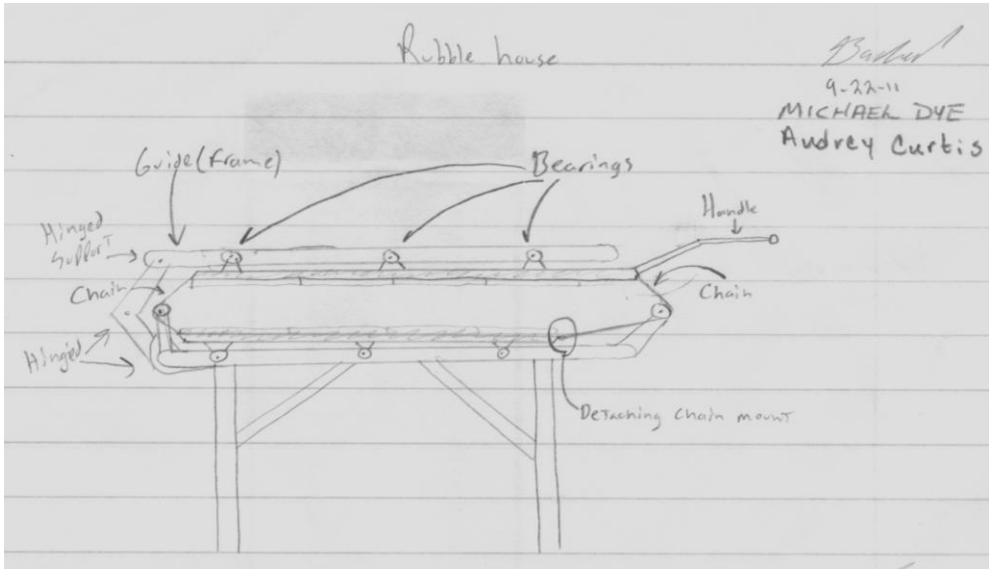
Faculty Involvement

- Apply coursework with simulated field learning
- Provide real problems with applications to real solutions

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Faculty Involvement

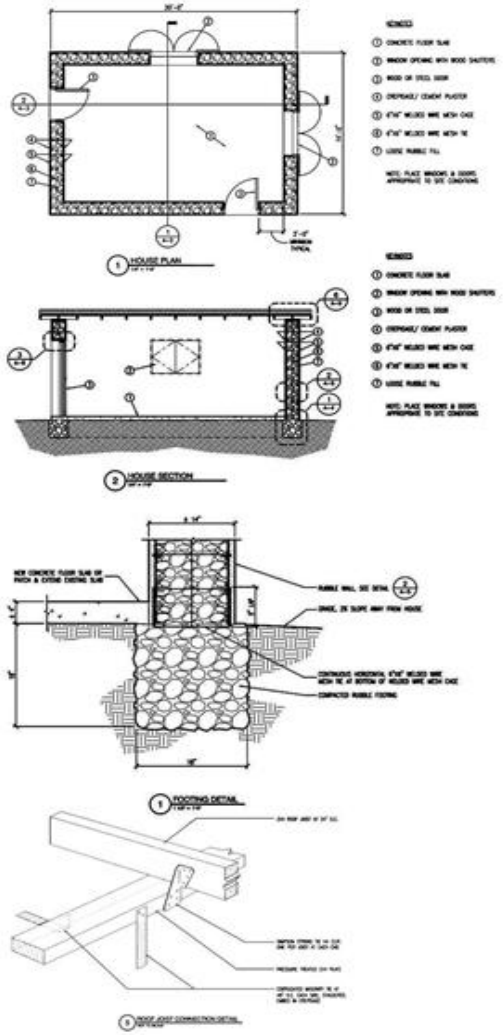




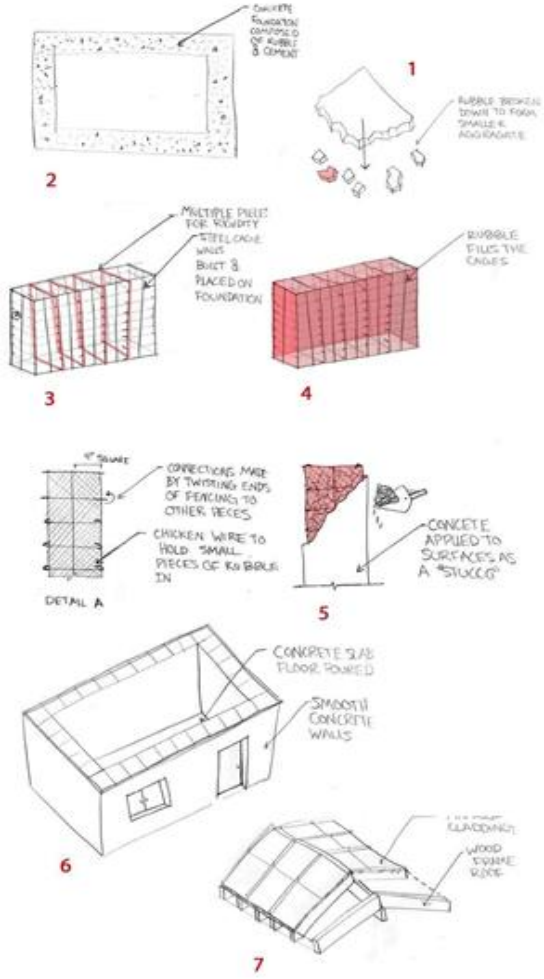
SOUTHERN POLYTECHNIC STATE UNIVERSITY

Faculty Involvement

BUILDING DETAILS



CONSTRUCTION PROCESS SKETCHES



RUBBLE HOUSE PROJECT

ANTONIO ALFIERI

o Design considerations learned from the organizers

^Using materials from a family's destroyed home allows them to remain in their old neighborhood. It aids with cleanup and solves complicated land-use issues. Construction materials are purchased locally, and Haitians are employed, boosting the local economy.

^Because of the strength of the steel basket and the fact that the contents are allowed to shift during an earthquake, --engineers believe the houses will withstand an 8.0 earthquake with only minor cosmetic damage.

o Design problems that were inherent in the system

^limited landfill space for storing the debris and fiscal challenges of importing new building materials.

^ways of making connections and working that would not require anything other than simple hand tools

^using inexpensive materials and labor to produce a house under $3000

o Design variations that could be proposed

^ using a rebar that is felxible in the wall structure to increase support and provide flexibilty to the walls

^ having better connection of foundation and wall, since the only connection is through gravity and concrete filing spaces between the walls and the foundation concrete

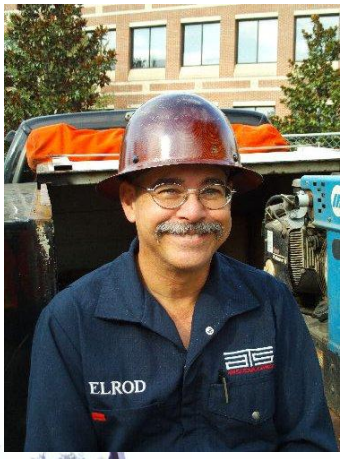
STATE UNIVERSITY

Community Interaction

- Develop ties with the community.
- Utilize media and public relations to maintain transparency.
- Local sponsors

SOUTHERN POLYTECHNIC STATE UNIVERSITY

ATS – Applied Technical Services
Marietta, GA



Other Sponsors

STEEL, LLC

C.W.M. CONTRACTING Co.

ATLANTA DEMOLITION
Preparing for Progress

PLANNING · ENGINEERING · LAND SURVEYING
PAUL LEE
CONSULTING ENGINEERING ASSOCIATES, INC.

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Future Plans

- Create forums for collaboration
- Promote further interdisciplinary involvement in projects
- Conduct a trip to Haiti

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Conclusions

- Field testing was completed with no injuries
- Data collection methods worked well
- Rigid or flexible? Complex behavior.
- Promising performance (Hor. Disp. 3.5 ft)
- Wider footings? Better footing wall connections?
- Wall connections need improvements
- Great student involvement

SOUTHERN POLYTECHNIC STATE UNIVERSITY

- Post-Failure

(a) Rubble-House after failure

(b) South-east corner.

(c) South-east corner bottom.

Potential Research Topics

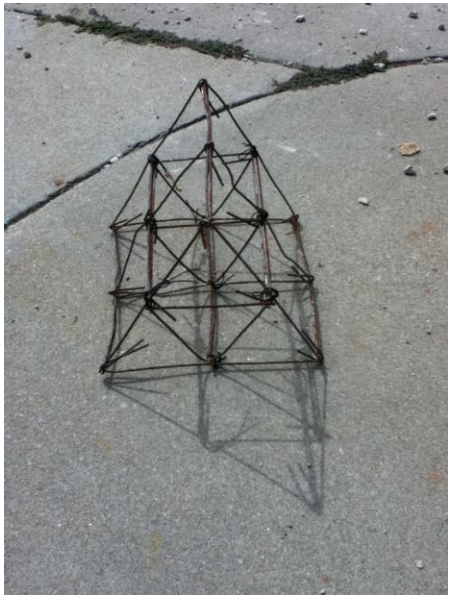
- Compaction rates to determine ideal rubble size
- Rocks as opposed to rubble
- Torsional stiffness at roof connections
- Uplift capacity of roof connections
- Effects of numerous small aftershocks on compaction/long term integrity
  (to help determine the best time to start construction after an earthquake)
- Effects of different thicknesses of concrete plaster
  (less plaster may reduce time/materials needed but require galvanized mesh)
- Effectiveness of different wire gauges
  (to determine minimum, acceptable and ideal gauge sizes)
- Effect of different sized wire mesh openings
  (eg 6, 4, 2 inch squares, or 2x6, 2x8, 3x6, 3x8 inch openings)
- Torsional resistance
- The effect of plywood sheathed joists on torsional resistance from seismic loads
- The effect of plywood sheathed joists on uplift and torsional resistance from wind loads
- The effect of plywood sheathed rafters on torsional resistance from seismic

THANK YOU….

SOUTHERN POLYTECHNIC STATE UNIVERSITY

Future Improvements

- Corner connections
- Wire basket with triangular compartments



SOUTHERN POLYTECHNIC STATE UNIVERSITY

Future Improvements

- Wall to roof connection
- Foundation to wall connection

SOUTHERN POLYTECHNIC STATE UNIVERSITY

SOUTHERN POLYTECHNIC STATE UNIVERSITY

- Dr. Wasim Barham is an assistant professor in the Civil and Construction Engineering Program at Southern Polytechnic State University, Marietta, Georgia. He received his doctoral degree from the State University of New York at Buffalo in 2005. He is currently teaching engineering mechanics and structural design related courses. His main research interest areas are finite element analysis, computational mechanics, and virtual reality.

- Dr. Pavan Meadati is an assistant professor in Construction Management Program, Southern Polytechnic State University, Marietta, Georgia. He received his doctoral degree from University of Nebraska, Lincoln in 2007. He is currently teaching Structural Design, Residential Construction, Building Information Modeling (BIM) and LEED related courses. His main research interest areas are BIM, RFID, and Applications of Information Technology in Construction.

- Jacob T. David is a senior in the Civil Engineering Technology degree program at Southern Polytechnic State University. His areas of interest are in structural and geotechnical applications. With David's background as a Research Assistant at Emory University and experience in volunteer management for non-profits, he currently serves as Project Assistant for the Rubble House team.

- Jeremy Holloman I come from a construction background, with several of my relatives having been involved in home and boat building. I spent three years in Honduras where I managed several masonry construction as well as assisting in El Salvador after the 2000 earthquakes. At Conscience International I serve as the Program Director for Latin America and the Caribbean as well as leading the Rubble House Program.

SOUTHERN POLYTECHNIC STATE UNIVERSITY